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THE FRAGMENT CONTAINMENT CHARACTERISTICS OF EXPLOSIVES BUILDINGS AND OTHER FORMS OF FRAGMENT PROTECTION FOR HD 1.1 AND HD 1.2 CHARGES UP TO 2.5 kg TNT EQUIVALENT

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PROGRAM AND MANAGEMENT SUPPORT
WEAPONS SYSTEMS RESEARCH LABORATORY

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TECHNICAL REPORT
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THE FRAGMENT CONTAINMENT CHARACTERISTICS OF EXPLOSIVES BUILDINGS AND OTHER FORMS OF FRAGMENT PROTECTION FOR HD 1.1 AND HD 1.2 CHARGES UP TO 2.5 kg TNT EQUIVALENT

R.B. Crockart and M.J. Bone

ABSTRACT

A series of trials was conducted in October 1988 to assess the primary fragment containment and secondary fragment generation characteristics of explosives buildings when subjected to HD 1.1 and HD 1.2 charges detonating within the building. A number of other fragment protection devices were tested and the results enabled the conclusion that the double brick cavity walls of these buildings plus 25 mm mild steel sheeting are acceptable containment to stop the fragment spread from charges up to 2.5 kg TNT equivalent. Care needs to be taken to provide adequate stand-off from walls and to ensure that the elevation angle of the containment exceeds 50°.

Tests showed that the rope mantle is unacceptable in providing containment, and the walls of environmental test chambers require additional protective screening or special additional testing under the proposed usage conditions to ensure adequate containment of fragments from a small quantity explosion.

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1. INTRODUCTION

1.1 Background

Explosives storage and processing locations are potentially hazardous to people within their immediate vicinity. The four potentially lethal effects of an inadvertent explosion, used in the assessment of safe separation, arise from the blast wave, the radiated heat from the fire ball, the projected primary fragments if not contained, and secondary fragments (rock, building material etc).

The potentially lethal effects of blast and radiated heat are predictable from a knowledge of the quantity of explosives and the distance to receptors, but more needs to be known to predict fragment effects. Factors difficult to predict, such as the fracture mechanics of typical HD 1.1 processing equipment or the fragment polarisation pattern of some HD 1.2 explosives under test or in storage, require that a conservative approach be taken to safety distances where fragments may be involved. Accordingly, minimum safety distances of 270 m for quantities above 50 kg or 200 m (< 50 kg) respectively are applied when it cannot be shown that fragments can be contained(ref.1,2).

The experiments to be reported here follow successful tests on reinforced concrete modules designed to contain the fragments from a 10 kg TNT equivalent source used in propellant manufacture(ref.3). Reinforced concrete modules are too bulky to be used in some locations where smaller quantities of explosives are being used. A cost effective approach was considered to be an adequately supported 25 mm steel plate.

Accordingly, three tests were performed wherein a 105 mm HE shell was detonated to simulate the effects of a 2.5 kg NEQ explosives incident with primary fragments, and bare plastic explosive charges at 2.5 kg and 700 g NEQ were detonated to assess secondary fragment generation.

1.2 The problem

Safety distance requirements are particularly restrictive in laboratory operations, in small arms ammunition filling operations, and in experimental propellant production plants involving small quantities of HD 1.1 explosives such as in a research environment. These safety distances must be applied when it cannot be proved that primary fragements would be contained and that no secondary or spalled fragments would be generated from the outside of the building. The problem is the same in any situation where only small quantities of HD 1.1 or HD 1.2 are being stored or processed.

1.3 Task aim

Although US safety tables infer that quantities below 5 lb (2.27 kg) can be contained in their explosives buildings, tests on the Australian explosives buildings, mainly erected during the second world war, had not been done before the tests reported here. There was an additional requirement to test proposals for internal fragment screens for this quantity. Accordingly, a task was planned which aimed at testing the containment of fragments from a 2.5 kg source against a number of structures, including building walls, suppressive screens and a duplication of a test chamber section.

2. SITE AND TARGET PREPARATION

2.1 Test site

The test site (made available by the Operational Safety Committee (Explosives)) was Building 255 at the Albion Explosives Factory (AEF). It had been planned to demolish the building as part of the current activity in relocating of the facility.

The structural detail of the building, which had a double cavity brick external wall and a double brick, no cavity, inner dividing wall, is shown in figures 1 and 2. These figures also show the layout of the three tests and an isometric view of the test involving the artillery shell (105 mm HE).

This particular building was located in an area allowing effective control of access, and the clearance distances met the demolition requirements. Prior to the tests, the asbestos cement roof had been removed to prevent dispersion of asbestos dust as a result of the explosions. Construction and site preparation for the tests, including removal of the roof and fabrication and positioning of target structures was performed by AEF personnel.

2.2 Explosives

The source of a uniformly fragmenting explosive was an Artillery Shell (105 mm HE M1) fitted with a nose closure plug (no fuse, but booster in fuse well), supplied by the Australian Army. Stemmed with Plantee Explosive No 4 (PE4) and initiated with a No 8 Detonator and fired by a RAAF Service Condenser Exploder, it constituted a 2.5 kg TNT equivalent HD 1.2 source.

Additional PE4 used to construct bare charges of 2.5 kg and 700 g initiated and fired in a similar manner to the 105 mm shell, made up Tests 2 and 3 of the trial sequence.

2.3 Targets

The targets or fragment containment proposals included double brick walls of both cavity and solid style, a 25 mm steel plate, a replicated section of an environmental test chamber and a traditional rope mantle. These are shown in figures 1 and 2.

2.4 Stand-off distance

The possibility of production of secondary fragments and/or spalling or scabbing off external walls from charges of 2.5 kg and smaller, was also to be investigated. In making these tests, it was decided to take the crater diameter (discussed in reference 4), as the minimum stand-off distance between explosive and containing walls. The required stand-off distance was calculated from the formula $D = 0.8\ Q^{1/3}$, Q being the TNT equivalent quantity in kilograms, D in metres and taken as 1.3 m for the 2.5 kg tests reported.

2.5 Steel plate

Experience from the 10 kg trials(ref.3) indicated that rigid attachment to the floor of any fragment shields was probably the reason for the very large forces generated at the securement points and potential was considered to exist for the shield to become a missile. As a result of this consideration, flexible securement was devised for the steel plate. The arrangement used in the securement of the plate is shown in figure 3. The flanges of the heavy-walled pipe, which were slotted and welded to the plate, were designed to be flush with the floor but free to move in the close fitting diamond saw recesses cut into the floor. Vertical movement of the plate, under impulsive blast loading, was restrained by the bending of the single taper flange beam attached to one side and the back of the plate. The plate and method of securement were compatible with the layout of the experimental propellant manufacturing plant in which it was proposed to be employed.

2.6 Test chamber section

A drawing of the test chamber section is shown in figure 4. Essentially the chamber was two 18 gauge mild steel plate sections separated by soft insulating material.

2.7 Walls

To assess the possible production of secondary fragments from the outer walls of the building, the outside surfaces immediately adjacent to the location of the shell were painted black and wood battens were attached to the walls at these locations for securing white painted 'canite' sheets. Any spalling or scabbing of the outer walls would be recorded as marks on the canite.

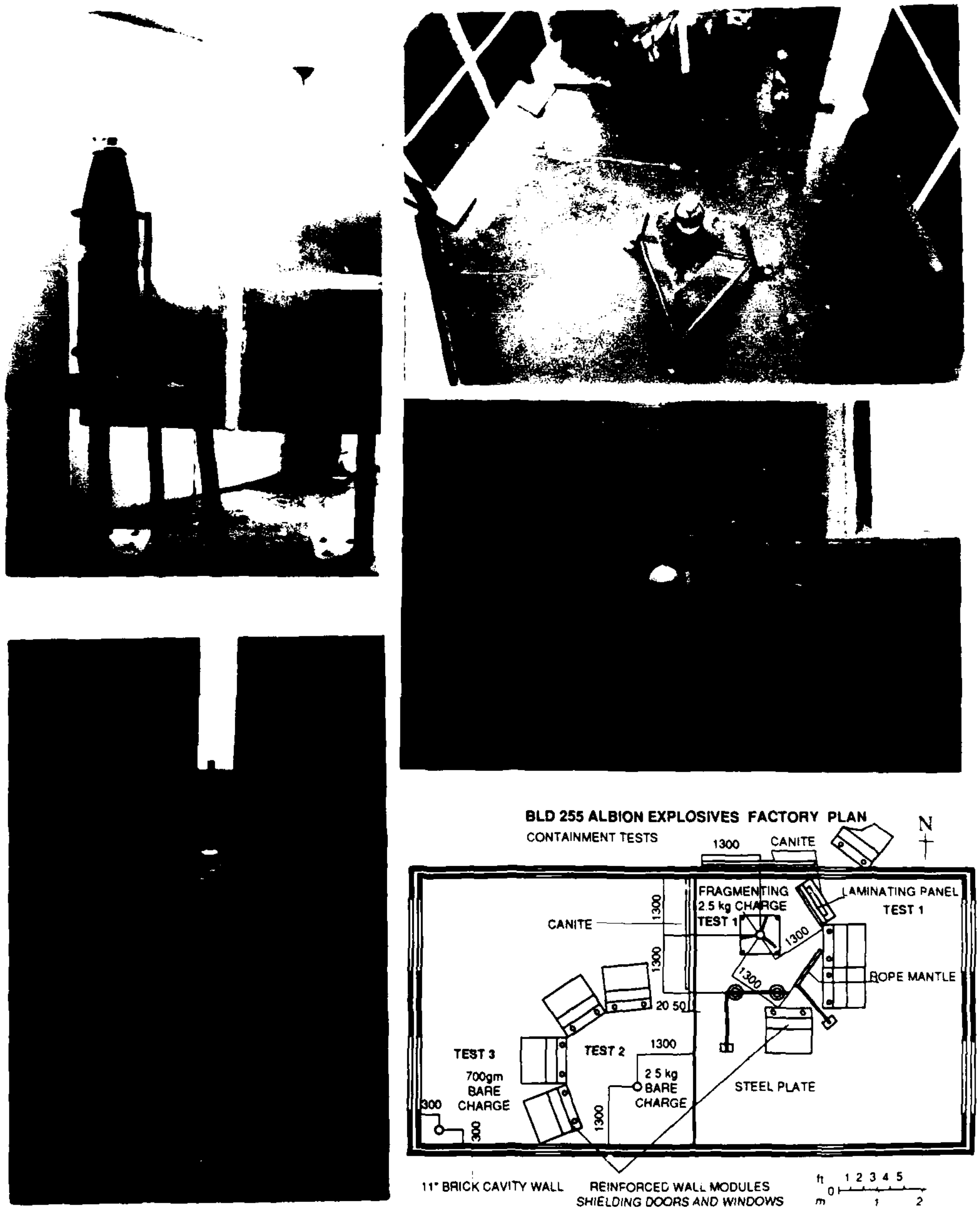

Figure 1. Plan view of containment test Albion Explosives Factory

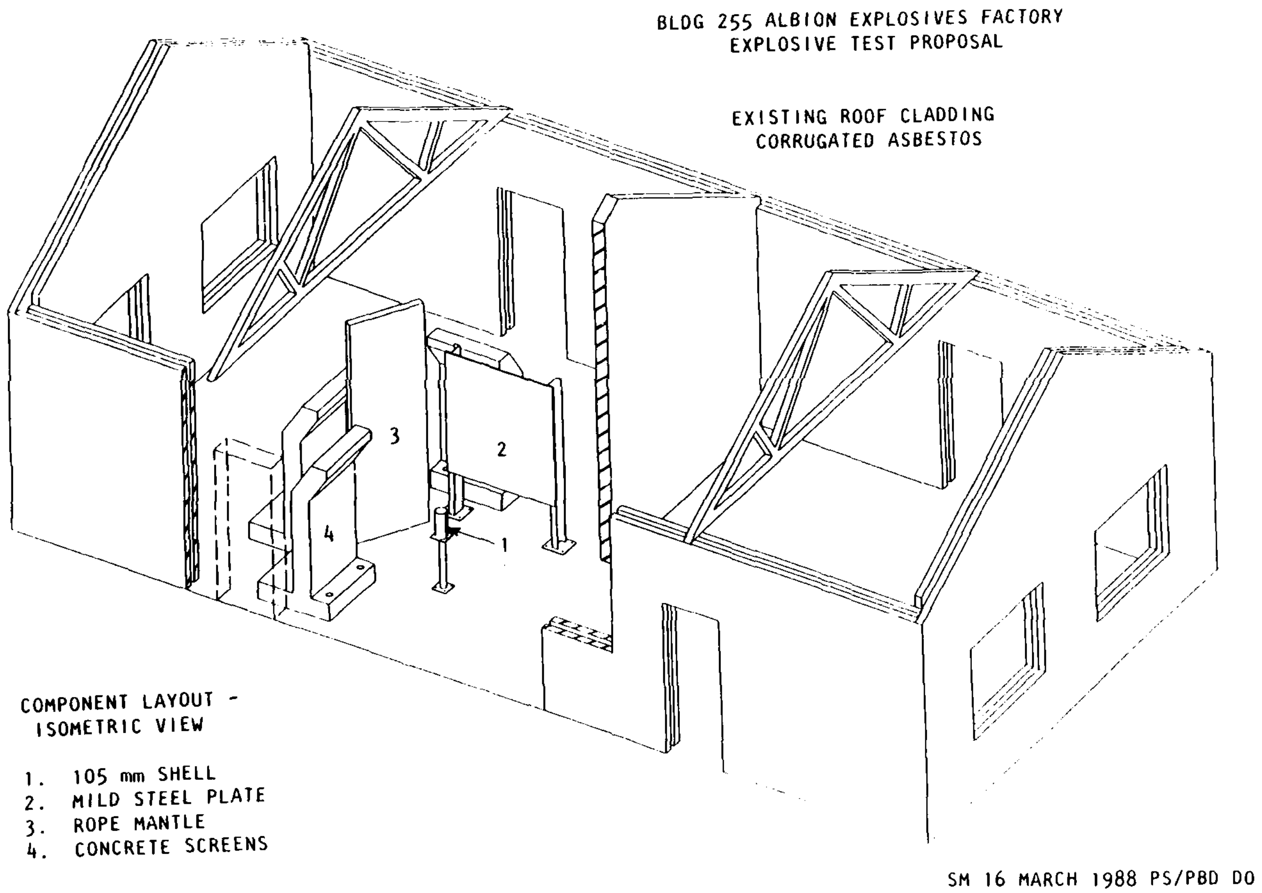

Figure 2. Component layout - isometric view

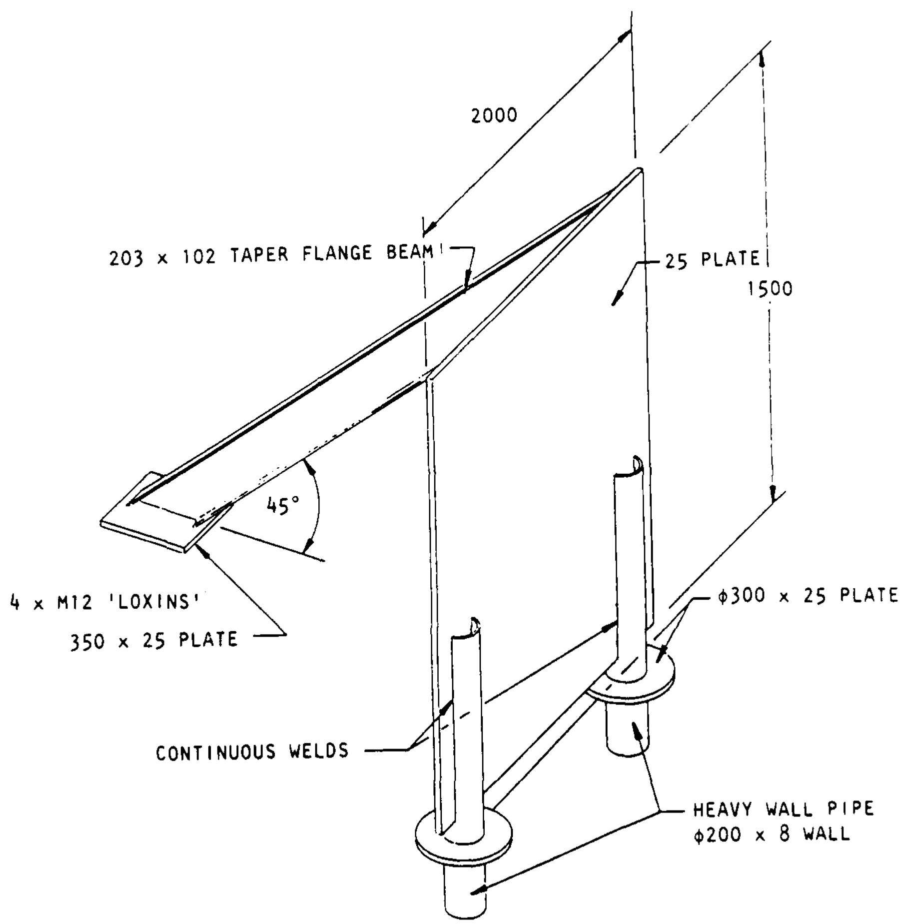

Figure 3. Steel plate unit

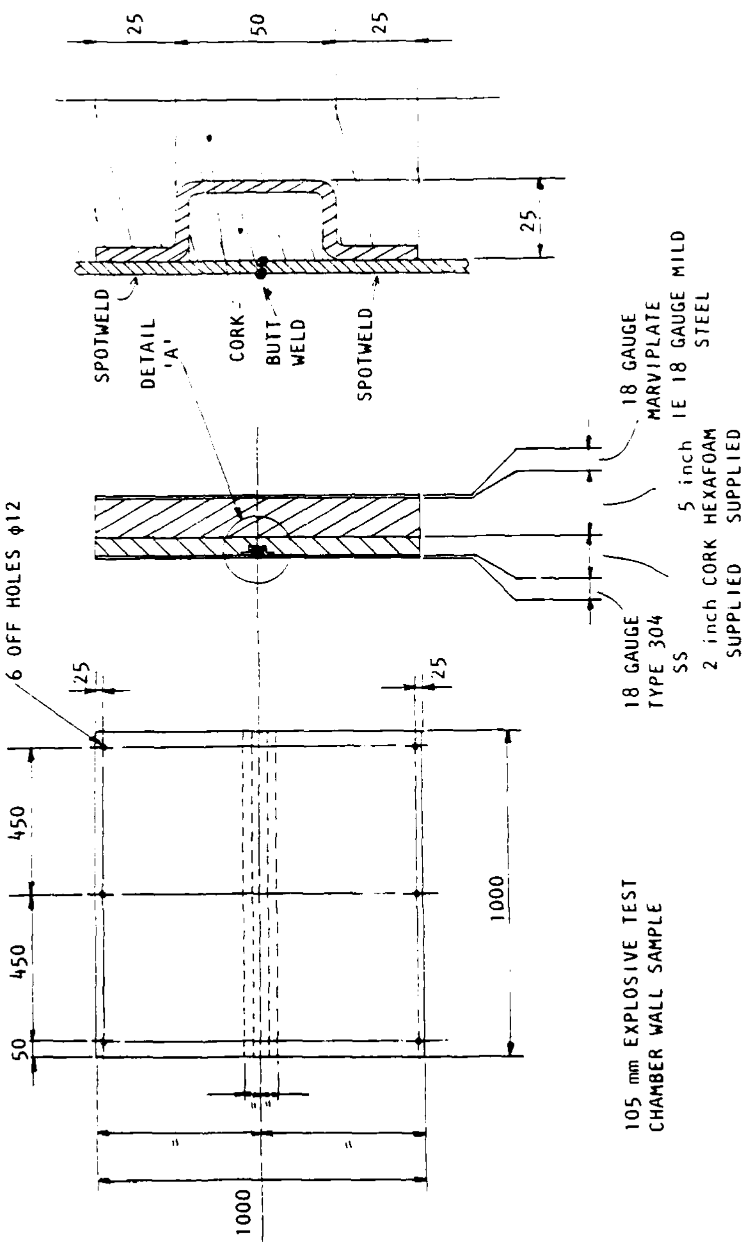

Figure 4. Test chamber wall sample (Artillery Shell Test)

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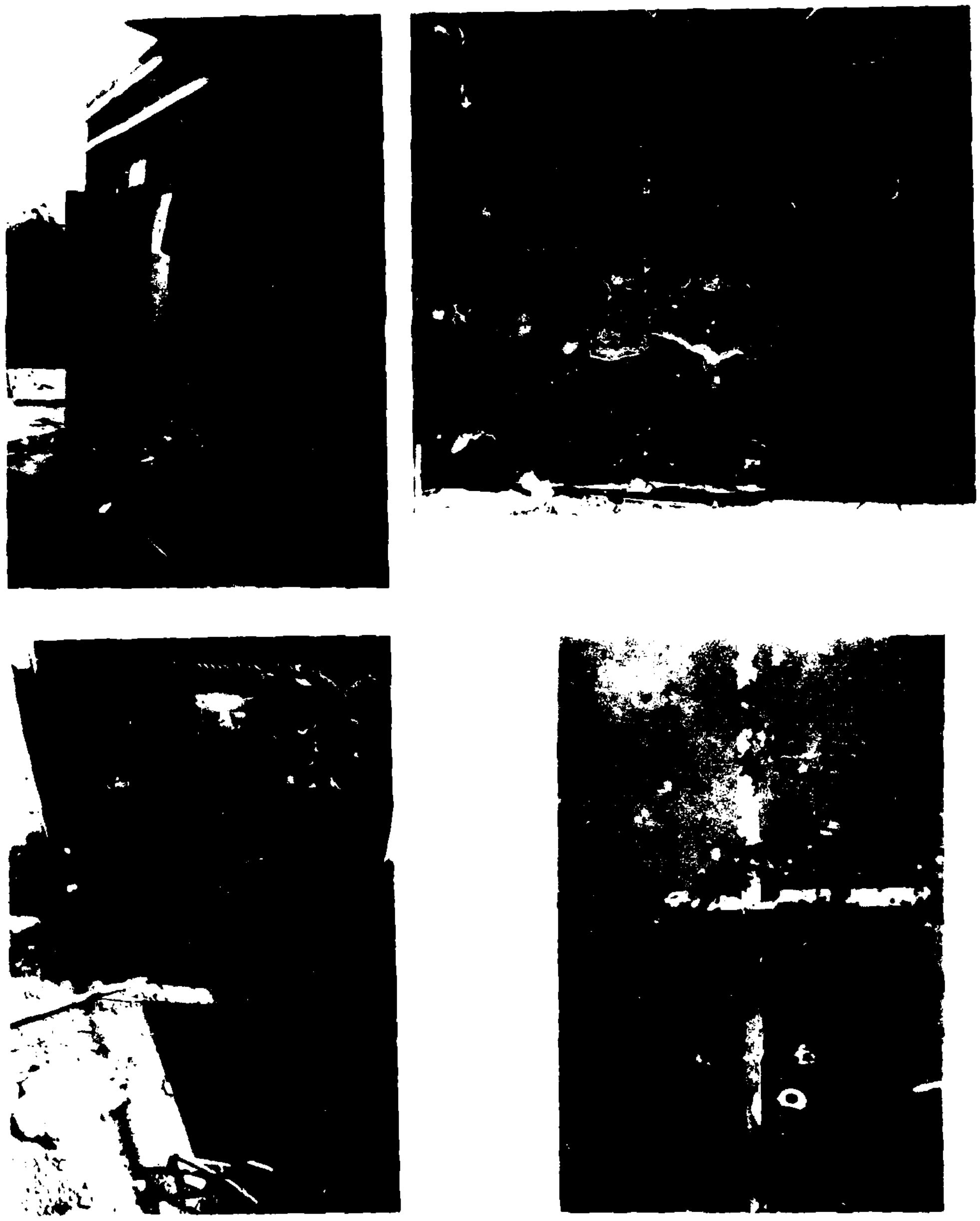

Figure 5. Artillery Shell Detonation - effect on walls

2.8 Rope mantle

The detailed construction of the rope mantle was not recorded but it was a typical rope mantle, used but serviceable and supported on two RSJ beams set into the floor at the prescribed distance. The base of the mantle may be seen in the top right hand photograph of figure 1, and the dismembered remnants on the lower left photograph of figure 5.

3. DETAILS OF TRIALS

The three tests were carried out during 11 to 13 October 1988 in accordance with the procedures at Annex A. All the explosives functioned on the first firing pulse.

3.1 105 mm test preparation

In the test of the shell it was considered important to prevent it from toppling before or during detonation. The shell remaining vertical would ensure a uniform spread of fragments to the surrounding targets and, in accordance with the results of a study conducted by Materials Research Laboratory (MRL), discussed in the next paragraph, would ensure that most fragments struck a target within the building. This requirement was satisfied by the ring and rod attachment shown in figure 1, top left photograph.

3.2 105 mm fragment distribution

The data provided by MRL is at Annex B. The pattern distribution was the result of a computer modelling program based on a lethality study carried out by the UK's Royal Armament Research and Development Establishment (RARDE). The distribution of fragments indicated by RARDE were in general agreement with the fragment spread from a detonating shell given in munitions effects manuals. The pattern of fragments were anticipated to fall inside an elevation angle of 45° with the maximum concentration at the centre points of the targets. As a substantial target existed in all directions to 55° above the nose of the shell, it was assessed that most fragments would remain close to the building. A search of the area after the trial proved these assumptions correct.

3.3 Screening of openings

The door and window openings were screened by the type of reinforced cement blocks used in the 10 kg Woomera-based trial(ref.3).

3.4 2.5 kg bare charge preparation

The 2.5 kg bare charge was constructed of sticks of PE4 moulded around a central wooden rod in rough semblance to the artillery shell.

It was located in the next bay of the building at the same stand-off distance to both types of building walls. The concrete wall modules blocks, as well as providing protection at the door and window openings, created a similar confining effect to that provided for the 105 mm shell.

3.5 700 g bare charge preparation

The 700 g bare charge was formed in the shape of a sphere and set on a platform representing a wooden bench such as might be found in explosives laboratories. The charge was located 30 cm away from a corner of the double brick cavity walls of the building.

Photographs of the three test sites, before initiation, are shown in figure 1.

4. RESULTS AND OBSERVATIONS

4.1 105 mm test results

The blast following the firing pulse was observed on a TV recorder. Small window fragments were seen being projected from the building. Later examination of the building showed that most of the wired-glass window sections imploded and were scattered around the bay in which the test was conducted, probably as a result of the negative pressure phase of the blast wave.

The results showed that the shell detonated in the vertical position and sent fragments equally in all directions in azimuth. The distribution in the vertical plane can be assessed, in a general way, by the impact marks shown on the steel plate and the environmental test chamber section shown in the photographs comprising figure 6. The remains of the white pressure sensitive tape, originally marking the projected vertical and horizontal axes of the shell can be seen, even though the test chamber section was blown off its mounts.

4.1.1 Steel plate

The number of fragments which struck the steel plate was assessed to be between 400 and 500. Of these three had sufficient energy to penetrate the plate and were found imbedded in the wall (as had many others which by-passed the fragment screens).

The large recovered fragments and a number of pin sized marks on the targets showed that there was a much wider distribution of masses from the ruptured shell case than indicated by the stated or desired weapon characteristics, Annex B refers. A detailed examination of the steel plate has begun in order to measure the impact area of the fragment strikes and their depth of penetration of this plate, to compare the fragment distribution mass and velocity with the model provided by MRL.

4.1.2 Test chamber and rope mantle

Both the representative test chamber section and the rope mantle were penetrated easily by the fragments. Erosion of the walls behind these targets and on the cement blocks was no different in appearance to that caused by unimpeded shell fragments.

4.1.3 Walls

The double brick outer wall under severe fragment attack, collapsed against the canite sheets and pushed their securing battens outwards. However, no marks of primary or secondary fragments from the walls were found on any of the canite sheets, other than rubbing marks from black painted sliding bricks.

The double brick internal wall, no cavity, produced what was considered to be a typical saucer-shaped spall, directly adjacent to the charge on the outer side of the wall. However it did not fall away until the canite was removed, and as for the outer wall, no primary or secondary fragment impacts were found in the soft canite sheets placed against this wall.

4.1.4 Illustrations

The effects described in the previous paragraphs are illustrated in the photographs comprising figures 5, 6, 7 and 8.

4.2 2.5 kg bare charge results

The detonation of the 2.5 kg bare charge was accompanied by an impulse sound and fire ball, as observed on the TV monitor, considerably greater than that of the shell. A door was seen flying off the building, which on closer examination was due to the projection of an unsecured cement block, located to protect the door opening.

Figure 6. Results of 105 mm detonation - rope mantle and chamber wall

Figure 7. Artillery Shell Detonation - continued

Figure 8. Artillery Shell Detonation - continued

Figure 9. Results of 2.5 kg bare charge detonation

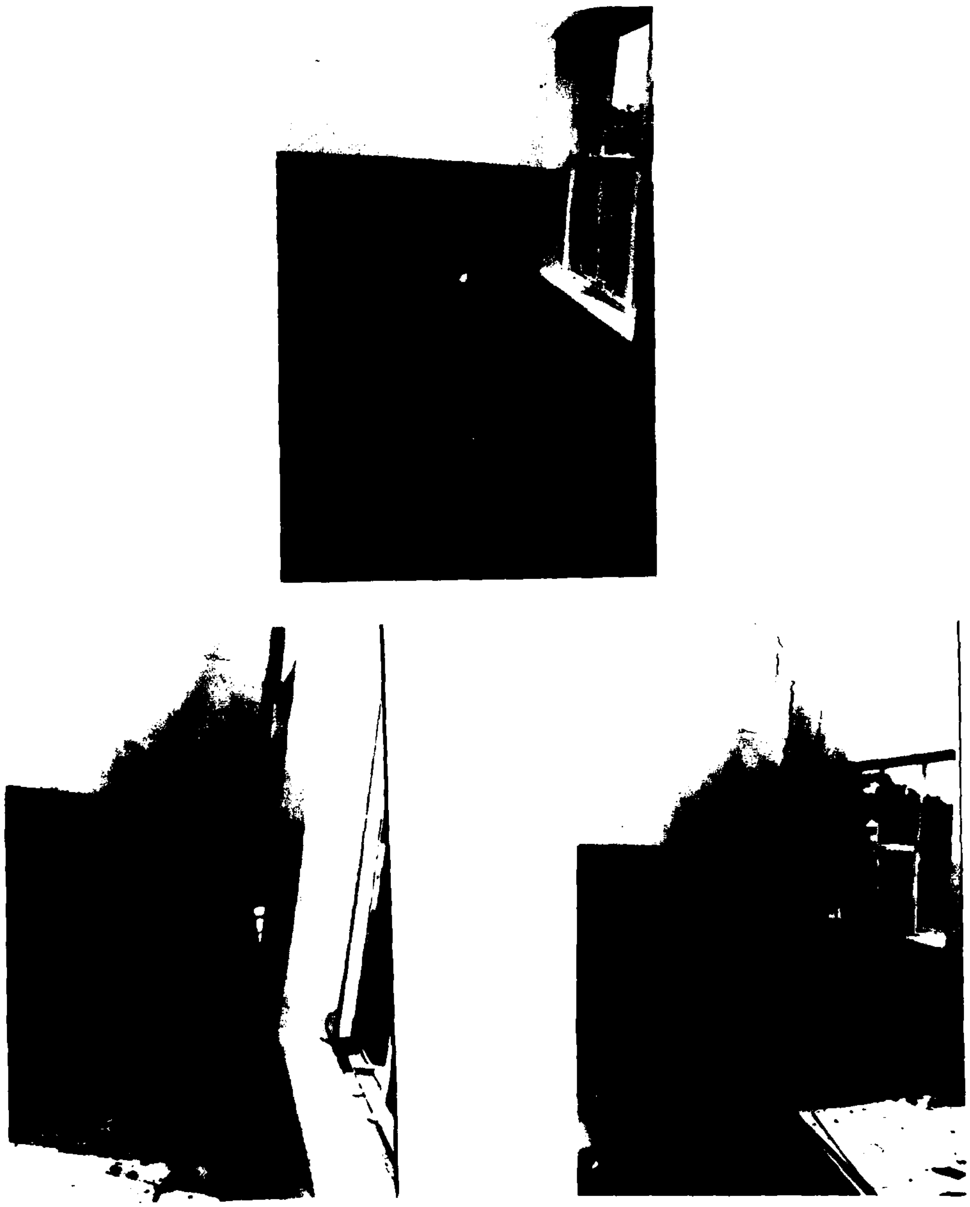

Figure 10. Results of 700 g bare charge detonation

Although the inner surface of the wall had been scorched by the fire ball and the outer walls bowed under the pressure, no spalling or scabbing of bricks from the outer wall or the outside of the inner wall were recorded. These results are illustrated in the photographs comprising figure 9.

4.3 700 g bare charge results

The effects of detonating a 700 g charge placed 30 cm from the outer walls of the magazine are shown in the photographs comprising figure 10.

Although an existing internal crack was opened and burn marks were left on the plaster coating the insides of the wall, there was no projection of bricks or fragments from the outer surfaces.

5. DISCUSSION OF RESULTS

5.1 The hazard

When the chemical energy of a detonating explosive disrupts its primary containment there is a wide distribution of kinetic energy in the primary fragments, unless specific steps are taken to control the break-up. When the pressure wave from a detonating explosive is reflected from the surface of a large container, such as a building, sections of the outer wall can be ejected with considerable kinetic energy producing secondary fragments. Both types of fragment constitute a hazard unless controlled.

The results of the tests reported here showed that the primary fragments from detonating sources of 2.5 kg TNT or less can be effectively reduced to an acceptable minimum by the typical double brick walls of the explosives building. Where the stand-off distance of the wall meets the crater diameter criterion, no spalling or scabbing or secondary fragments of the wall will occur. Door and window openings may be screened by reinforced cement traverses or structures closer in, such as the 25 mm mild steel plate construction tested in this trial.

5.2 Collapse of walls

Possible explanations for the collapse of the walls tested by detonation of a 105 mm shell include the fragments 'out-running' the blast within the crater distance, allowing the follow-up blast to attack a wall already weakened by impacting fragments, or pressure wave focussing, or an unnoticeable weakness caused by weathering.

5.3 Securement of screens

It was observed that the 25 mm steel plates had been lifted vertically approximately 12 mm by the explosion and the support leg basins had also been disturbed. Allowing the steel plate securement devices to yield elastically under the blast impulse seems to be a viable method of retaining fragment screens in place in the event of an inadvertent detonation.

5.4 Rope mantles and test chambers

The rope mantle was not effective against the smaller high energy fragments produced in the test. The test chamber section results showed that environmental tests on HD 1.2 munitions should always require the use of additional fragment screens.

6. CONCLUSIONS AND RECOMMENDATIONS

It is concluded that, for HD 1.1 situations where there are minimal or no primary fragments, typical double brick walls will not generate lethal secondary fragments, for explosives quantities up to 2.5 kg NEQ and where separation of the charge from the wall is $0.8\,Q^{1/3}$ m or greater.

It is concluded that, for HD 1.2 situations up to 2.5 kg NEQ, effective primary fragment containment can be expected from typical double brick walls provided that;

(a) charges are located at, or further than 0.8 $Q^{1/3}$ m from the walls,

(b) the wall is of sufficient height, relative to the charge, to intercept all low angle fragments,

(c) adequate precautions are taken to ensure that door and window openings are screened.

It is concluded that 25 mm mild steel plate, suitably mounted to allow some yielding movement under shock loading of the explosion, will provide adequate fragment containment at a separation distance of 0.8 $Q^{1/3}$ m from the charge.

Rope mantles do not provide containment for primary fragments, and their use is not recommended in such situations.

7. ACKNOWLEDGEMENTS

The authors wish to recognise the cooperation and supportive effort extended by staff at both Albion Explosives Factory and Materials Research Laboratory, and particularly to Mr Ray Sweetman (AEF) and Mr John Donaldson (MEF) for their participation.

REFERENCES

No.	Author	Title
1	-	"D/ESTC Leaflet 5 Quantity Distances for Above Ground Storage".
2	-	"Operational Safety Committee (Explosives) 82/2 Handling of Quantities of Explosives up to 50 kg Above Ground".
3	Bone, M.J. and Henderson, B.	"The Containment Characteristics of a Portable Reinforced Concrete Wall Unit in a Small Explosives Incident". WSRL-TR-44/88 to be published
4	-	"D/ESTC Leaflet 6 Annex E page 24. Buildings and Traverses for Military Explosives 1980 (Provisional)".

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ANNEX A

DSTO WSRL **WEAPONS SYSTEMS RESEARCH LABORATORY**

File Ref: W6068/3/5

Sec OSC(E)

For information:

Sec ESTC

SMALL QUANTITY EXPLOSIVES CONTAINMENT TRIAL - TASK DST 4B/017

1. Enclosed is the plan of action, including procedures, for the small quantity containment trial to be conducted in Building 255, Albion Explosives Factory on 10-12 October, 1988.

2. The trial is to assess the fragment containment characteristics of a number of traditional and proposed protective devices used for small scale R&D processes with explosives.

3. There will be two trials, the first is the detonation of a 105 mm HE shell in the configuration shown in the plan and isometric drawings enclosed as Annexes A & B. The 105 mm shell was considered appropriate, firstly because, one was available and secondly because when initiated at the end, it is a source of uniform high speed fragments.

4. The second test will be of a bare 500 gm charge in a situation typical of explosives laboratory use.

5. The procedures planned for the one day involved in trial preparation and the two days for the actual firings are enclosed as Annex C, D & E.

R.B. CROCKART
Task Manager

Encl

4 Oct 88

PREPARATION ACTIVITIES FOR CONTAINMENT TRIALS
ALBION EXPLOSIVES FACTORY 10-12 OCTOBER 1988

1. Monday 10 October 1988 is set aside to check that the preparation made for the containment trials meets the requirements specified in the accompanying procedures.

2. ***Area Security***

Area Security over the trial period has already been discussed with Mr Tom Barnes, Officer in Charge of the area who has made the initial arrangements to ensure the area out to 400m is cleared of people and that any people between 400m and 800m are under cover during the trials (and for any period after if there is a misfire). In addition the access roads into the firing site will be controlled at the points marked C on the enclosed map of the area, also showing the 400 and 800m zones.

3. Although the firing point has been selected, there is a requirement to select a suitable, alternative site for the observers. Any observers will be controlled through Mr Mick Bone who is assisting the firing officer, Bob Crockart, while Mr John Donaldson will be accompanying and assisting the firing officer.

4. Communication between the Officer in Charge of Security, Tom Barnes, the firing point and the observer location will be tested and operating methods agreed to match the requirements specified in the enclosed procedures.

5. ***Area Preparation***

Although advice from Albion indicates that the test items are in place in Building 255, checks will be made on fragment containment geometry and floor securement from the explosion site of the 105mm shell.

Examination will be made of a bench or table to support the 500gm base charge to be detonated 30cms from the building wall in the second containment test on 12 October 1988.

Explosives Stores Preparation

6. In conjunction with Mr Tom Barnes a suitable location will be selected and the nose closure plug on the 105mm projectile will be removed and the fuse-well checked. As understood from the army the booster and supplementary charges will not be in-situ. The closure plug will be replaced hand-tight.

7. A check will be made on the plasticity of the PE4 and consideration given to any need for tamping of the PE4 to ensure good communication with the main filling.

8. Arrangements will be made to weigh out 500gms of PE4 for the second trial.

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105mm Shell Fragment Containment Test

Tuesday 11 October 1988

1. ***Equipment Requirements***

   a. *Detonator Electric No 8 - 1 off*

   b. *PE4 - 2 sticks about 1kg*

   c. *Dynamo Condenser Exploder (Beethoven MK11)*

   d. *Charging handle and Box Fusion Test for Beethoven*

   e. *Fuse Heads Type F53 - 1 off*

   f. *Adhesive Insulation Tape*

   g. *Red Flags*

   h. *104mm Shell*

   i. *35mm Camera*

   k. *Safety Ohmmeter*

2. ***Trial Personnel***

R.B. Crockart	*Firing Officer and Task Manager*
I. Donaldson	*Assistant Firing Officer*
M. Bone	*Engineering Officer*
T. Barnes	*Area Security*

3. ***Initial Preparation (Approx. 8.30 a.m. - 9.30 a.m.***

   a. *Position shell on stand, closure plug in place.*

   b. *Locate detonator, fusehead Type F53 in separate nearbye locations (remote from access route of observers)*

   c. *Ensure red flags in place at all access points to the area*

   d. *Photograph the installation before the explosion*

   e. *Allow observers into the area .nd,if asked,explain the final preparation procedures.*

   f. *Request observers to leave under control of Mr Mick Bone*

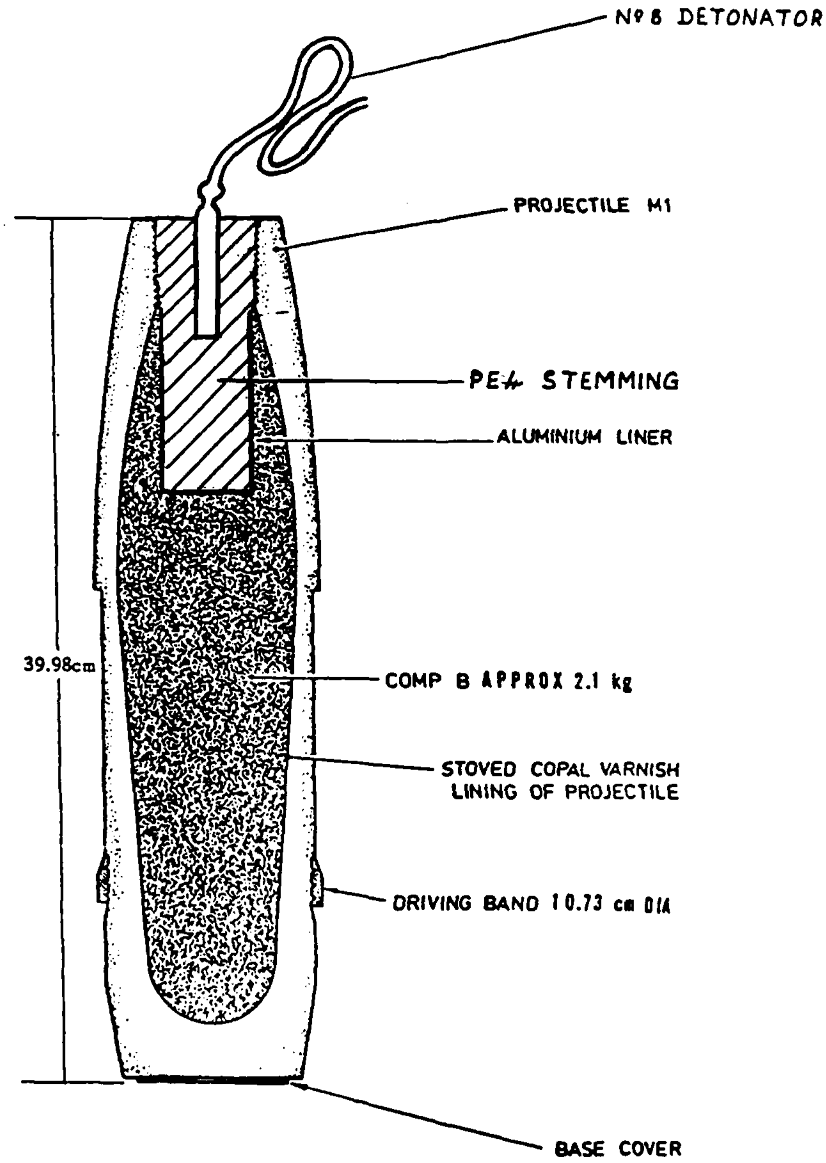
4. ***Final Preparation 9.30 am - 10.30 am***

   a. *Check Detonator continuity in accordance with RAAF Procedure (para 112 enclosed refers).*

   b. *Check firing circuit and Beethoven exploder using an F53 in accordance with Demolition Method D1 (para 206 enclosed refers).*

   c. *Remove nose closure plug and tamp PE4 into the fuse well in accordance with the enclosed drawing. Rectify a cavity for the detonator.*

PROJECTILE H.E., M1, W/SUPPL. CHG. FOR 105 MM HOWITZER



BARE CHARGE TEST - 12 OCTOBER 1988

1. ***Equipment***

   a. *Same as for 105 mm test with exception of 105 mm shell.*

2. ***Personnel***

   a. *As for 105 mm test.*

3. ***Initial Preparation***

   a. *Weigh and mould 500 gm of PE4 into a ball; rectify a hole for the detonator.*

   b. *Place on wooden spoke on table 29.5cms from double brick and from cavity brick walls.*

   c. *Ensure canite fragment collectors are relocated to the outside of the wall adjacent to the explosion site.*

   d. *Allow any observers to check installation.*

4. *Proceed with final preparation and firing as for the 105 mm shell test.*

5. *Collect and Record the results.*

ANNEX B

MASS GROUP (g)	MASS GROUP (grains)	AVERAGE MASS (grains)	SQRT MASS (g)	FRAGMENT NUMBER	CUMULATIVE FRAGMENT NUMBER	FRAGMENT MASS (g)	CUMULATIVE FRAGMENT MASS (g)
0.00- 0.05	0.00- 0.77	0.39	0.00	1099.3530	3899.9587	27.4838	11895.1816
0.05- 0.10	0.77- 1.54	1.16	0.22	365.1849	2800.6057	27.3889	11867.6982
0.10- 0.15	1.54- 2.31	1.93	0.32	218.3435	2435.4209	27.2929	11840.3096
0.15- 0.20	2.31- 3.09	2.70	0.39	155.4203	2217.0774	27.1986	11813.0166
0.20- 0.30	3.09- 4.63	3.86	0.45	216.4573	2061.6570	54.1143	11785.8184
0.30- 0.50	4.63 7.72	6.17	0.55	267.7706	1845.1996	107.1082	11731.7041
0.50- 0.75	7.72- 11.57	9.65	0.71	210.9043	1577.4290	131.8152	11624.5957
0.75- 1.00	11.57- 15.43	13.50	0.87	148.0663	1366.5247	129.5581	11492.7803
1.00- 1.50	15.43- 23.15	19.29	1.00	202.0191	1218.4583	252.5239	11363.2227
1.50- 2.00	23.15- 30.86	27.01	1.22	139.4394	1016.4391	244.0189	11110.6982
2.00- 3.00	30.86- 46.30	38.58	1.41	185.5363	876.9997	463.8407	10866.6797
3.00- 5.00	46.30- 77.16	61.73	1.73	209.8266	691.4634	839.3066	10402.8389
5.00- 7.50	77.16- 115.74	96.45	2.24	144.8369	481.6368	905.2304	9563.5322
7.50- 10.00	115.74- 154.32	135.03	2.74	88.1510	336.7999	771.3214	8658.3018
10.00- 15.00	154.32- 231.48	192.90	3.16	98.2132	248.6489	1227.6659	7886.9805
15.00- 20.00	231.48- 308.64	270.06	3.87	52.2547	150.4356	914.4578	6659.3145
20.00- 30.000	308.64- 462.96	385.80	4.47	48.9416	98.1809	1223.5409	5444.8564
30.00- 50.00	462.96- 771.60	716.28	5.48	30.2496	49.2393	1209.9836	4521.3154
50.00- 75.00	771.60- 1157.40	964.50	7.07	9.7805	18.9897	611.2825	3311.3318
75.00- 100.00	1157.40- 1543.20	1350.30	8.66	3.1638	9.2092	276.8367	2700.0493
100.00- 150.00	1543.20- 2314.80	1929.00	10.00	2.1163	6.0453	264.5425	2423.2126
150.00- 200.00	2314.80- 3086.40	2700.60	12.25	0.8815	3.9290	154.2551	2158.6702
200.00- 300.00	3086.40- 4629.60	3858.00	14.14	0.9060	3.0475	226.4895	2004.4150
300.00- 500.00	4629.60- 7716.00	6172.80	17.32	0.8684	2.1415	347.3628	1777.9255
500.00- 750.00	7716.00- 11574.00	9645.00	22.36	0.5201	1.2731	325.0833	1430.5627
750.00- 1000.00	11574.00- 15432.00	13503.00	27.39	0.2741	0.7530	239.8798	1105.4795
1000.00- 1500.00	15432.00- 23148.00	19290.00	31.62	0.2515	0.4789	314.3775	865.5997
1500.00- 2000.00	23148.00- 30864.00	27006.00	38.73	0.1047	0.2274	183.1928	551.2222
2000.00- 4000.00	30864.00- 61728.00	46296.00	44.72	0.1227	0.1227	368.0294	368.0294

TOTAL FRAGMENT NUMBER 3899.9585

TOTAL CASE MASS (g) 11895.1826

TOTAL EXPL MASS (g) 2434.9700

ZONE NUMBER	POLAR ZONES (degrees)	AVERAGE FRAGMENT MASS (grains)	AVERAGE FRAGMENT MASS (g)	TOTAL FRAGMENT MASS (grains)	TOTAL FRAGMENT MASS (g)	TOTAL FRAGMENT NUMBER	FRAGMENTS PER STERADIAN	INITIAL VELOCITY (ft/s)	INITIAL VELOCITY (m/s)
1	0.0- 5.0	0.00	0.000	0.0	0.00	0.00	0.0	0.0	0.0
2	5.0- 10.0	0.00	0.000	0.0	0.00	0.00	0.0	0.0	0.0
3	10.0- 15.0	0.00	0.000	0.0	0.00	0.00	0.0	0.0	0.0
4	15.0- 20.0	0.00	0.000	0.0	0.00	0.00	0.0	0.0	0.0
5	20.0- 25.0	0.00	0.000	0.0	0.00	0.00	0.0	0.0	0.0
6	25.0- 30.0	23.87	1.547	0.0	0.00	0.00	0.0	3542.9	1079.9
7	30.0- 35.0	23.61	1.530	0.2	0.01	0.01	0.0	3603.4	1098.3
8	35.0- 40.0	23.54	1.525	1.8	0.11	0.07	0.2	2620.7	1103.6
9	40.0- 45.0	23.44	1.519	12.8	0.83	0.55	1.5	3645.7	111.2
10	45.0- 50.0	23.33	1.512	70.2	4.55	3.01	7.4	3677.4	1120.9
11	50.0- 55.0	23.22	1.505	288.3	18.68	12.42	28.6	3717.6	1133.1
12	55.0- 60.0	23.14	1.499	895.6	58.04	38.71	83.7	3769.3	1148.9
13	60.0- 65.0	23.19	1.502	2136.4	138.44	92.14	138.5	3836.8	1169.5
14	65.0- 70.0	23.60	1.529	4035.6	261.51	171.00	337.7	3926.0	1196.6
15	70.0- 75.0	24.90	1.613	6420.9	416.07	257.88	493.3	4037.0	1230.5
16	75.0- 80.0	27.84	1.804	9469.0	613.59	340.14	635.6	4143.8	1263.0
17	80.0- 85.0	32.54	2.108	13908.9	901.30	427.49	786.6	4196.5	1279.1
18	85.0- 90.0	37.66	2.440	19778.8	1281.67	525.25	959.2	4180.6	1274.2
19	90.0- 95.0	42.03	2.724	24920.4	1614.85	592.90	1082.7	4124.2	1257.1
20	95.0- 100.0	46.14	2.990	26100.1	1691.30	565.68	1040.9	4046.0	1233.2
21	100.0- 115.0	51.94	3.366	22408.9	1452.10	431.44	806.2	3938.4	1200.4
22	105.0- 110.0	63.64	4.124	16285.7	1055.32	255.91	489.5	3780.0	1152.1
23	110.0- 115.0	90.66	5.874	10617.9	688.05	117.12	231.3	3579.6	1088.0
24	115.0- 120.0	153.76	9.964	6432.2	416.81	41.83	86.0	3356.3	1023.0
25	120.0- 125.0	299.25	19.392	3637.4	235.70	12.15	26.3	3177.1	968.4
26	125.0- 130.0	665.98	43.156	2149.3	139.28	3.23	7.4	2977.4	907.5
27	130.0- 135.0	1567.64	101.583	1764.4	114.34	1.13	2.8	2754.5	839.6
28	135.0- 140.0	2371.05	153.645	1915.5	124.13	0.81	2.2	2662.2	811.4
29	140.0- 145.0	2423.17	157.022	1989.8	128.94	0.82	2.5	2673.7	815.0
30	145.0- 150.0	2119.92	137.372	1744.0	113.01	0.82	2.8	2743.3	836.2
31	150.0- 155.0	1574.77	102.046	1359.7	88.11	0.86	3.4	2907.4	886.2
32	155.0- 160.0	1058.35	68.581	1131.5	73.32	1.07	5.1	3184.0	970.5
33	160.0- 165.0	812.56	52.654	1116.9	72.38	1.37	8.3	3414.7	1040.8
34	165.0- 170.0	735.01	47.629	1105.4	71.63	1.50	12.7	3513.2	1070.8
35	170.0- 175.0	713.65	46.244	907.7	58.82	1.27	17.8	3543.2	1080.0
36	175.0- 180.0	707.16	45.824	961.3	62.30	1.36	56.9	3552.5	1082.8

TOTAL FRAGMENT MASS (g) 11895.18

TOTAL FRAGMENT MASS (grains) 183566.45

TOTAL FRAGMENT NUMBER 3899.96

AVERAGE FRAGMENT VELOCITY (m/s) 1188.66

DAMAGE CRITERION: PERSONNEL CASUALTIES

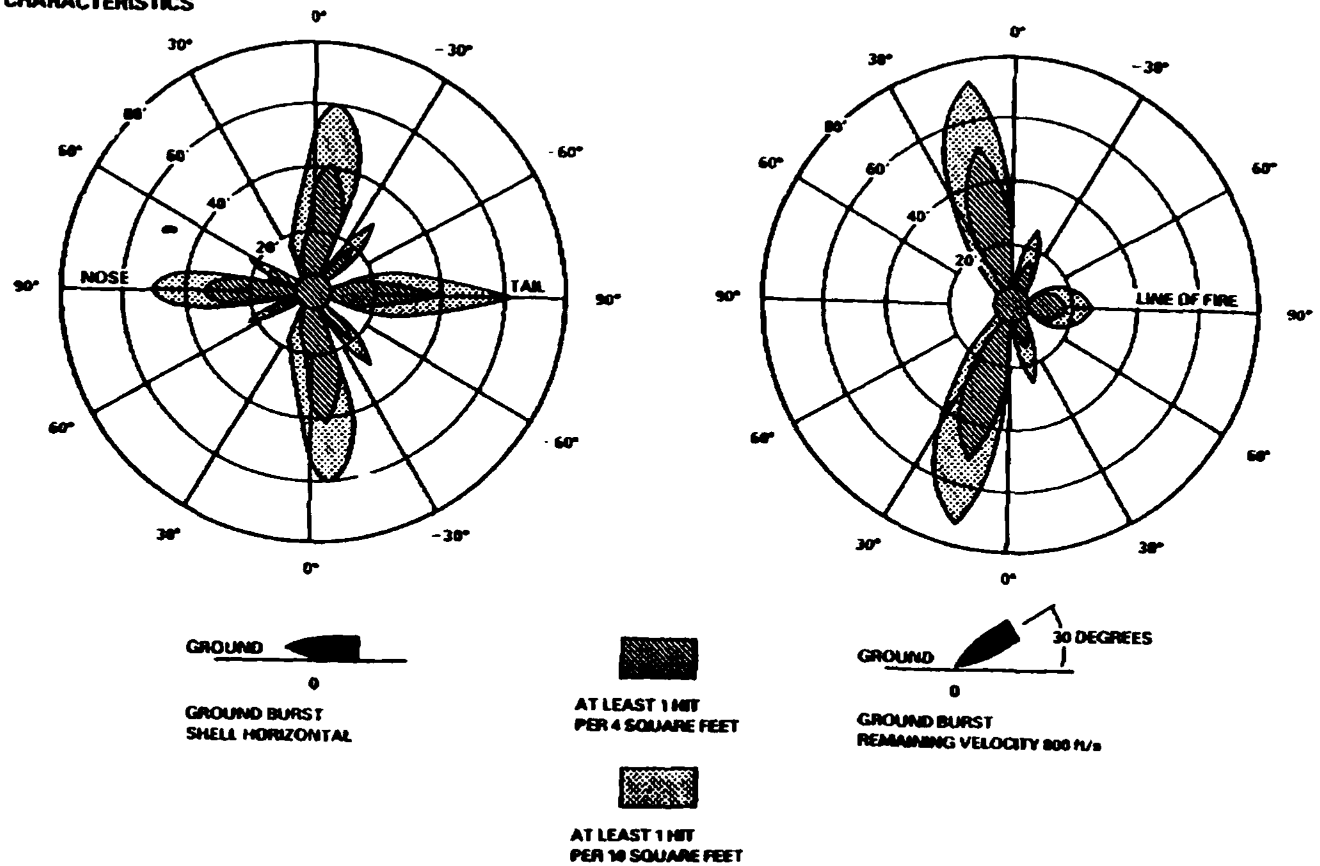


Figure 2-3. (U) Damage pattern for 105-mm HE projectile (Sheet 1 of 2)

DAMAGE CRITERION: PERFORATION OF 1/8-INCH MILD STEEL PLATE

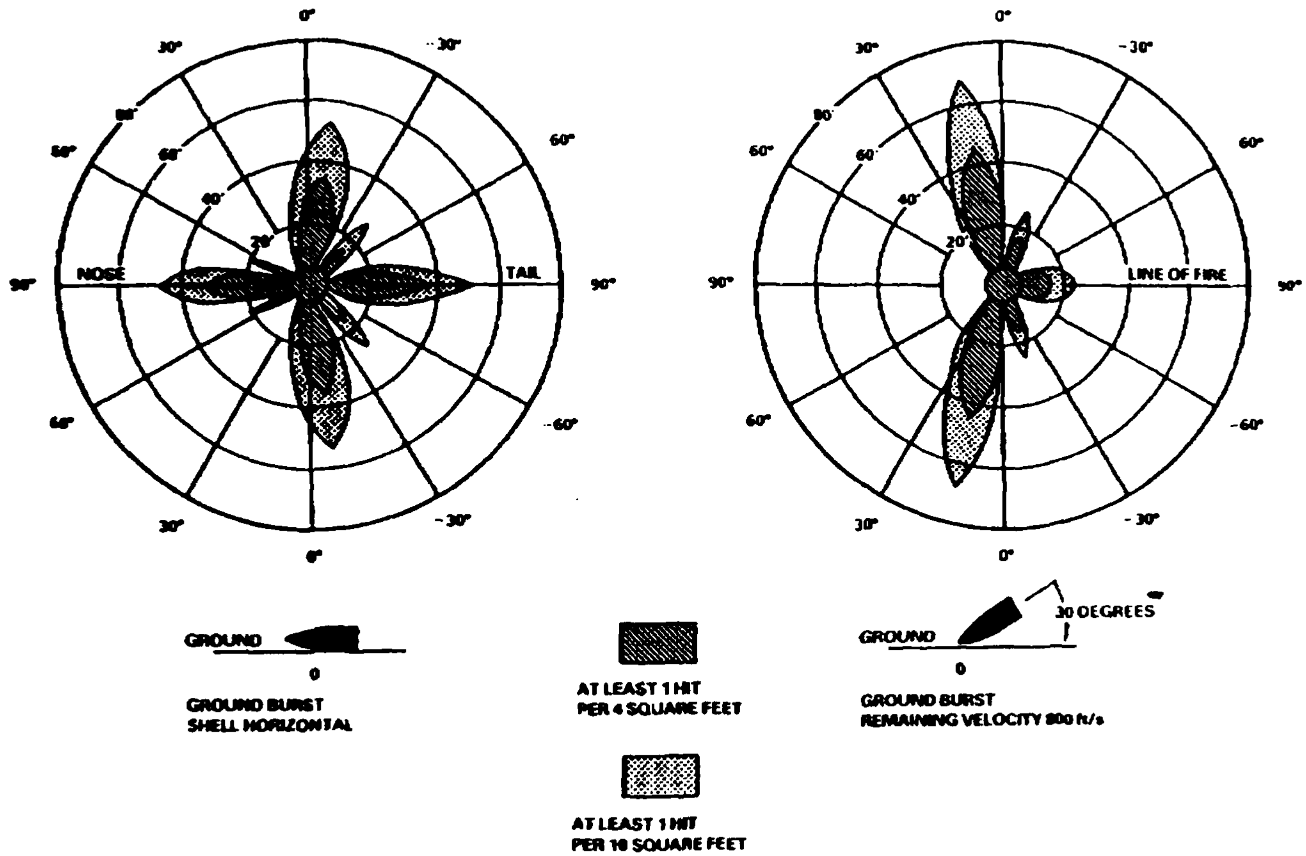


Figure 2-3. (U) Damage pattern for 105-mm HE projectile (Sheet 2 of 2)

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5 PERSONAL AUTHOR (S)

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17 SUMMARY OR ABSTRACT
(if this is security classified, the announcement of this report will be similarly classified)

A series of trials was conducted in October 1988 to assess the primary fragment containment and secondary fragment generation characteristics of explosives buildings when subjected to HD 1.1 and HD 1.2 charges detonating within the building. A number of other fragment protection devices were tested and the results enabled the conclusion that the double brick cavity walls of these buildings plus 25 mm mild steel sheeting are acceptable containment to stop the fragment spread from charges up to 2.5 kg TNT equivalent. Care needs to be taken to provide adequate stand-off from walls and to ensure that the elevation angle of the containment exceeds 50°.

Tests showed that the rope mantle is unacceptable in providing containment, and the walls of environmental test chambers require additional protective screening or special additional testing under the proposed usage conditions to ensure adequate containment of fragments from a small quantity explosion.

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